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The Impact of HIV Testing on the Spread of HIV Infection

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HIV is a non-curable, infectious disease that affects over 400 new individuals every year in British Columbia. There are four main phases of HIV infection: acute seroconversion; early HIV illness; established HIV illness; and AIDS defining illness. The spread of any infectious disease can be predicted by using the following equation:

$$R_0 = \beta D c$$

R_0 is the secondary spread of an agent, β is the efficiency of transmission, D is the duration of, infectiousness, and c is the number of individuals that are exposed to the infection.

The efficiency of transmission (β) in HIV and the duration of infectiousness (D) are directly related to the amount of virus circulating in the blood and the amount of antibody available to combat the virus in the host. HIV antibodies usually develop in individuals between 4 to 6 weeks after becoming infected with HIV and the amount of antibody in the host gradually increases until it reaches its maximum point. The amount of antibody and virus in an infected individual provides an indication of which phase of HIV illness the individual is in.

Acute seroconversion (less than 28 days) refers to the stage of infection prior to the development of an antibody response. During acute seroconversion, HIV can be detected in the blood by the use of a nucleic acid amplification test (NAAT) within two days of infection. Standard antibody tests that are used to detect an HIV infection do not differentiate between an established infection (greater than 170 days) and an early HIV infection (less than 170 days). Detuned antibody testing can be done to detect early HIV illness when antibody levels are low.

The ability to detect acute and recent HIV infections is essential in linking individuals to appropriate care and in preventing the spread of infection. Research studies have found that once individuals are informed of their HIV diagnosis, they will reduce their practice of high-risk sex by about one half.

Through mathematical modeling, we would like an algorithm to assist us in answering the following questions:

1. For each acute HIV infection detected by the NAAT, how many HIV infections could be prevented assuming that there is a change in behaviour in the newly infected person?

2. For each early HIV infection detected by the detuned antibody test, how many HIV infections will be prevented assuming that there is a change in behaviour in the newly infected person?

CD4 cells are white blood cells responsible for coordinating much of the immune response and are damaged by HIV. The depletion of CD4 cells results in individuals being susceptible to other types of infections. CD4 cell counts in a healthy non-HIV infected person range between 400-1,400 cells/μL. An HIV positive individual with a CD4 cell count <200 cells/μL is at risk of rapid disease progression.

Viral loads describe the amount of HIV in an individual's blood. An HIV positive individual with over 100,000 copies/mL of blood plasma is considered high. During the acute stage of HIV infection, the viral load is extremely high and will decrease over the first six months post-transmission until it plateaus, in the absence of treatment, to a set point. Note that this set point varies from person to person.

Drugs called antiretrovirals are used to lower the amount of virus in the blood. Currently, antiretroviral therapy is widely recommended for patients with a CD4 cell count below 200 cells/μL, regardless of viral load levels or the absence of symptoms. In other words, an individual with a CD4 cell count of over 500 cells/μL and a viral load of 150,000 copies/mL would not be on therapy. There is evidence to suggest that these treatment guidelines have caused a 75% increase in new HIV infections among high risk individuals. From a public health perspective, individuals with such high viral loads are highly infectious and will hamper the overall efforts to reduce the burden of HIV/AIDS disease. Recall that not all individuals with a CD4 cell count of over 500 cells/μL will have such high viral loads since the viral load set point varies from person to person.

From a public health perspective, individuals with high viral loads, high CD4 cell counts, and are not on antiretroviral therapy, probes the following question.

3. For each untreated individual with a high viral load and CD4 cell count, how many HIV infections will be transmitted?